Ocean Data Assimilation Research at GFDL

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Project Summary

Estimating the state of the Earth System is critical for monitoring our planet's climate and for predicting changes to it on time scales from months to decades. Toward these ends, the vast number of atmospheric observations and the growing number of ocean observations must be combined with model estimates of the state of the Earth System by means of data assimilation systems. This project explores the development of new data assimilation techniques using state-of-the-art **coupled** climate models and applies these techniques to detecting climate change, improving forecasts on seasonal to interannual time scales while providing estimates of their uncertainty, and improving our understanding of predictability at decadal time scales in order to provide a foundation for the development of a NOAA capability for decadal forecasts. This capability will provide the Nation's decision and policy makers with the best possible climate information on critical problems such abrupt climate change, changes in hurricane activity, drought, and sea-level rise.

Accomplishments

1. Development of Coupled Data Assimilation System using GFDL's coupled climate model (CM2)

   An ensemble filtering coupled data assimilation system using the GFDL's coupled climate model has been developed and tested, for the purpose of climate detection and SI forecasts. This system also serves as a test bed for understanding the predictability of larger time scale variability, such as NAO, AMI and THC etc. Currently, the system can be configured for either/both atmospheric and oceanic data assimilations (ADA/ODA). The corrected variables for the atmosphere include temperature, moisture, wind and surface pressure, and the corrected variables for the ocean include temperature, salinity, currents and wind stress. Other assimilation components (land/ice etc.) can feasibly be added if observations are applicable.

2. Climate Detection

   A series of assimilation experiments have be done within a perfect model framework for climate detection:
   - An ODA experiment based on the 20th-century ocean observing network (XBTs, CTD...) shows that the ODA process in the CDA system is able to detect the signals of climate changes in ocean heat content, only

assimilating the observed ocean temperature into the ocean state variables in the coupled model.

- An ODA experiment based on the 21st-century ocean observing network (Argo) shows that the assimilation of ocean temperature and salinity is able to reconstruct the large time scale thermohaline structures at middle and high latitudes. In particular, the decadal trend of the North Atlantic (NA) meridional overturning circulation (MOC) has been retrieved very well.
- A CDA (ADA+ODA) experiment based on the 20th-century ocean observing network and the atmospheric `reanalysis' data shows the fully-coupled assimilation improves significantly the estimate of ocean climate with a systematic error due to the lack of salinity source information. Particularly, the interannual variability of the NA MOC is retrieved very well due to the correction of the sea-surface forcings from the ADA.
- A CDA (ADA+ODA) experiment based on the 21th-century ocean observing network and the atmospheric `reanalysis' data shows the fully-coupled assimilation utilizing both the ocean temperature and salinity observations retrieves the ocean thermohaline structures very precisely. Particularly, both the interannual variability and decadal trend of the NA MOC is reconstructed with a high accuracy since the CDA system builds up a correct thermohaline structure by ODA and correct sea-surface forcings by ADA.

3. Impact of CDA's initialization of coupled model on SI forecasts

Based on the ODA, ADA and CDA products described above, a series of ENSO forecast experiments is on going for understanding the model's sensitivity to the coupled initial conditions. These sensitivity studies help improve the predictability of SI variability described by the coupled numerical system so as to improve the forecast skills eventually.

<u>Publications</u>

Zhang, S., M. J. Harrison, A. T. Wittenberg, A. Rosati, J. L. Anderson, and V. Balaji, 2005: Initialization of an ENSO Forecast System using a parallelized ensemble filter. *Monthly Weather Review*, **133(11)**, 3176-3201.

Zhang, S., M. J. Harrison, A. Rosati, and A. Wittenberg, 2006: Coupled ensemble data assimilation for Global Oceanic Climate Studies, Part I: System design and evaluation. *Monthly Weather Review*, in press.

Zhang, S., A. Rosati, and M. J. Harrison, 2006: Detection of multi-decadal ocean capability within a coupled ensemble data assimilation system. JGR Oceans, submitted.

The output from ODA experiments is available at
http://nomads/nomads/forms/assimilation.html